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## LOOMIS'S "CONTRIBUTIONS TO METEOROLOGY"

*Contributions to Meteorology.* By Elias Loomis, LL.D., Professor of Natural Philosophy and Astronomy in Yale College, &c. Revised Edition. (New Haven, Conn., U.S., 1885.)

IT is now fifty years since Prof. Loomis's attention was directed to the study of meteorology, his interest in the subject having been awakened by Redfield's investigations respecting the phenomena and laws of storms. During the first forty years his principal writings were elaborate discussions of the great storm which occurred in America in December 1836, and an equally remarkable storm which occurred in Europe shortly after the American storm, and an account of another United States storm in February 1842, which in a part of its course was accompanied by a tornado of unusual violence. The chief outcome of these investigations was a new method of charting observations, now so familiar to all the world in our weather maps, and the demonstration of the capital fact in meteorology, that in storms the movement of the wind is spirally inwards, circulating from right to left about the centre of the cyclone.

The generally imperfect character of the barometric observations for a long time precluded all attempts at any satisfactory investigation of the storms and weather of the United States; and it was not till 1871, when the Signal Service was organised, with its uniform methods of observation and reliable barometers, that the data required for the investigation was supplied. When two years' observations had accumulated, Prof. Loomis resumed his inquiries, and from July 1874 a series of papers by him, entitled "Contributions to Meteorology" have appeared from time to time in the *American Journal of Science*. A large number of these we have noticed in NATURE as they appeared. As the subjects investigated were taken up without any regard to systematic order, and as a change of views has necessarily come about as the investigations proceeded, Prof. Loomis has wisely resolved to reduce them to a more systematic form and incorporate into the revised work the results of observations now available, not only from the United States, but also from Europe and other parts of the world. The present pamphlet contains the first chapter of this revision, and the subject dealt with is the areas of low atmospheric pressure, their form and magnitude, and the direction and velocity of their movements.

As regards the forms of areas of low pressures, or cyclones as they are conveniently termed, the greatest and least diameters of all the cyclones represented on the Weather Maps of the Signal Service during a period of three years were actually measured, with the result that the average ratio of the longest diameter to the shortest was 1·94. In 53 per cent. of the whole number of cases the ratio was 1·5; in 33 per cent. 2; in 11 per cent. 3; and in 3 per cent. 4. Similarly the Atlantic storms, as delineated on Hoffmeyer's charts for a period of three years, have been examined, and the measurements show that the ratio of the longest diameter of the cyclones to the shortest is 1·70; and that while in 54 per cent. of the whole number of cases the ratio was 1·5, in 17 per cent. it was 2, and in 1 per cent. 3—thus showing a marked deficiency of very elongated low pressure areas over the Atlantic Ocean as compared with the United States.

Observations show that the longest diameter of cyclones may be turned in any azimuth. In the States it is most frequently directed towards a point somewhat East of North, the point towards which the longest diameter is most frequently directed being N. 36° E. The average direction is sensibly the same for the cyclones of the Mississippi Valley and for those of the Atlantic coast. Over the Atlantic Ocean the direction of the longest diameters are more equally distributed in azimuth than they are in the United States, but the point towards which the longest diameter is most frequently directed is N. 35° E., which corresponds almost exactly with the direction found for the United States.

The cyclones of the tropics frequently exhibit a violence greater than is ever known in the storms of the middle latitudes, but their geographical extent is comparatively small. The inclination of the winds inwards upon the centre is shown to be more strongly marked in tropical cyclones than in most storms of the middle latitudes. From an examination of the weather maps of the Signal Service it is found that in the United States a low pressure area, with only one system of cyclonic winds, frequently has a diameter of 1600 English miles, and Hoffmeyer's charts show that cyclones over the Atlantic have frequently diameters of 2000 English miles. Widespread areas of low barometer, having several centres of cyclonic action, may have a diameter of 6000 English miles or may even form a belt extending nearly, if not entirely, round the globe between the parallels of 40° and 50° N. lat. On the other hand, tropical cyclones are often only 500 miles in diameter, and are occasionally of still less dimensions.

When low pressure areas are very much elongated, two or three cyclonic centres are frequently included within the same area of low pressure. Though these cyclonic centres are occasionally of equal depth, yet they are more generally of very unequal depth and intensity. The weather charts of the morning of March 9, 1876, showed a very large area of low pressure overspreading Europe and the Atlantic Ocean, having a principal centre of low pressure in the north of Scotland, around which violent winds prevailed, rising to 12 on Beaufort's scale, with very steep gradients on the western side of the cyclone. About the same time, and within the same widespread low pressure area, there were four other cyclones, with their centres at St. Petersburg, South Russia, south coasts of the Black Sea, and over the Caspian Sea, respectively.

As an illustration of one of the more extensive areas of low pressure, Prof. Loomis adduces the great barometric depression of June 7, 1882, as shown on the International Weather Map of the Signal Service of that day. This area of low pressure covered the whole of Asia, apparently extending from the equator to a considerable distance beyond the North Pole; it covered the whole of Europe with the exception of a small portion of its southern margin, and also the northern part of the Atlantic Ocean and stretched across the central portion of North America to the Pacific Ocean: thus extending

through 320 degrees of longitude. The principal low centre, 29·200 inches, was north of the Caspian Sea; a second low centre, 29·400 inches, was over the northern part of India; a third low centre, 29·600 inches, over the Gulf of St. Lawrence; a fourth low centre, 29·800 inches, over China; a fifth low centre, 29·800 inches, north-east of Japan; and if every part of this large portion of the earth's surface had been sufficiently represented by observing stations several other subordinate low centres would doubtless have been exhibited. On the other hand, a centre of high pressure, 30·400 inches, was found over the Atlantic Ocean; a second, 30·200 inches, over the south-eastern part of the United States; and a third, over the eastern part of the Pacific near latitude 30° N. The area of high pressure formed a belt closely following the parallels of 30°—35° and extending through at least 240 degrees of longitude, but interrupted by the Asiatic Continent.

We drew attention five years ago to the all-important bearings of these areas of high and low pressure on the weather in all the regions of the globe over which anomalously high and low barometers at any time prevail (NATURE, vols. xxi., xxii. and xxiii.). But the importance of this department of meteorology is much enhanced when it is considered that it is through a careful record of the appearance and disappearance in different regions of the globe of these cyclonic and anti-cyclonic areas and an investigation of the causes determining their form, position, and intensity from time to time that we may hope to reach the solution of the problem of the weather. In prosecuting this large inquiry, the results of Prof. Loomis's careful measurements of meteorological phenomena, as detailed in the revised edition of his "Contributions" now before us, form one of the best guides we at present possess.

*Direction of Movement of Areas of Low Pressure.*—Areas of low pressure, or cyclones, seldom remain stationary in the same position for many hours. The centre of low pressure generally changes its position steadily from hour to hour, and everywhere there is observed a marked uniformity in the direction of this movement. Prof. Loomis gives several charts showing the progressive movement of cyclones in different parts of the world, including one showing nearly all the different storm tracts delineated on the International Weather Maps of the United States Signal Service for a period of more than four years. Maury's Storm Charts are also brought under review. The lowest latitude reached by the centre of any cyclone, which has been distinctly traced, is 6° 1′ N., and there are only eight cases of cyclones whose paths have been traced to points south of lat. 10° N.

Observations indicate that, both in the Pacific and Atlantic, gales are of extremely rare occurrence within six degrees of the equator, and, when they do occur, the barometric depression is small, and the cyclonic character of the winds indistinctly marked. But in low latitudes, a little higher than six degrees, gales are more frequent over the Pacific than over the Atlantic Ocean.

Tropical storms which are found to pursue a westerly course are limited to two regions of the globe—viz. the Atlantic Ocean, but particularly its western portion, near the West India Islands, and the region south of the continent of Asia. As regards the Pacific, no cyclone has ever been observed, except near Asia or its outlying islands.

As regards the tracks of tropical cyclones in the neighbourhood of the West Indies, the teaching of the data represented on the International Charts is that nearly all the areas of low barometer which occur within the tropics and advance westwards, instead of following the ordinary course of the trade winds, advance in a direction somewhat north of west. Of these West Indian cyclones, 88 per cent occurred in August, September, and October, thus leaving only 12 per cent. for the other nine months of the year. On the other hand, of the Asiatic cyclones 52 per cent. occurred in September, October, and November, and 43 per cent. in April, May, and June, thus leaving only 5 per cent. for the other six months. There is, therefore, a marked seasonal difference as to the frequency of the tropical cyclones of the Atlantic as compared with the Pacific: in the Atlantic they are almost exclusively confined to the autumn, but in the Pacific they are nearly as frequent in spring as in autumn.

The average direction of the course of the Asiatic cyclones, while moving westward, is 38° north of west, which closely accords with that found for West Indian cyclones. But, as regards the onward progress of tropical cyclones, whilst Asiatic cyclones advance westwards at the average rate of 8 English miles per hour, the average velocity of West Indian cyclones is double that amount. Asiatic cyclones come around to a due north course about lat. 19°·8 N., but West Indian cyclones do not assume a due northerly course till, on the average of instances, lat. 30° N. is reached. In the Pacific the average course of cyclones, after turning eastward, was 35° E. of N., and their velocity was 9·8 miles, which is scarcely half of the velocity of the West Indian cyclones. These striking and vital differences between the tropical cyclones of the Atlantic and the Pacific will doubtless play no unimportant part in the development of the theory of the cyclone.

An examination of Prof. Loomis's chart of storm-tracks for the northern hemisphere, with wind charts indicating the prevailing direction of the wind, shows a remarkable correspondence between the two classes of facts. Examining the point more narrowly, Prof. Loomis finds that for the middle region of the Atlantic, near lat. 50°, the average direction of storm paths corresponds very closely with that of the average direction of the wind; but in the western part of the Atlantic the average course of storms is considerably more northerly than that of the wind, while in the eastern part it is more southerly. These results, which fairly accord with those derived from tropical storms, seem to indicate, in the opinion of the author, that in the middle latitudes of the northern hemisphere the direction of progress of storm-centres is not the same as that of the average wind, but is sensibly affected by some other causes; and that the results derived from observations in the China Sea indicate that one of the causes is the prevalent direction of the wind which immediately follows a storm. The subject is further prosecuted by an examination of the prevailing winds and storm-tracks during the three winter months for the ten winters ending 1882 of that portion of the United States between long. 90° W. and the Rocky Mountains. The result of this somewhat exhaustive comparison is similar to that derived from the observa-

tions on the Atlantic—there being observed no rigorous correspondence between the average direction of the movement of storm-centres and the prevailing wind; but that in some regions the average course of storm-centres is more northerly than that of the wind, and in some regions more southerly.

While in middle latitudes the generally progressive movement of cyclones is in an easterly direction, cyclonic areas are occasionally observed, both in Europe and America, advancing to westward. After a careful investigation of forty-one of the most decided cases which have occurred of these westerly movements of cyclones, it is considered that the following conclusions are warranted—viz. that the westerly movement of low-pressure centres is due to a fall of rain or snow, in most cases unusually great, in the region towards which the low centre advances; and the influence of one low-pressure area acting apparently as an attractive force upon another adjacent low-pressure area; to the influence exerted by two areas of high pressure, not far apart, by which a new movement is imparted to the air included between them, a new low centre being sometimes developed; or to the influence of a high pressure on the north-east side of a low-pressure area, when the gradients on the south-west side of the low area are slight, in which case the centre of the low-pressure area may be crowded towards the south-west.

*Rate of Progress of Cyclones.*—The rate of progress of the United States storms for thirteen years has been calculated, and the results arranged according to the months, and expressed in miles per hour. The average rate of progress for the year is 28·4 miles, rising to the maximum, 34·2 miles in February, and falling to the minimum, 22·6 miles, in August. As regards different years, the variation is also much greater in the winter than in the summer months. Thus, in November, 1878, the rate was 21·2 miles per hour, but in the same month of the following year it was 40·7 miles; and, on the other hand, in July, 1882, the rate was 19·8 miles, but in July, 1881, it was 26·6 miles—the difference between the extremes of November being thus 19·5 miles, and in July only 6·8 miles.

In Europe during the five years ending 1880 the mean annual rate of progress was 16·7 miles, rising to the maximum, 19·0 miles, in October, and falling to the minimum, 14·0 miles, in August. Hence the onward movement of storms in the United States is two-thirds greater than in Europe, the rate of excess for the United States over Europe being 1·9 in winter, and 1·5 in summer. On the mean of the year the average onward movement of storms is, in miles per hour, 28·4 for the United States, 18·0 for the middle latitudes of the Atlantic, 16·7· for Europe, 14·7 for the West Indies, and 8·5 for the Bay of Bengal and the China Sea.

Prof. Loomis is led to conclude that the general system of atmospheric circulation, consisting of the trades of equatorial regions and the westerly winds of the middle latitudes, is the primary cause which determines both the direction and velocity of the movement of storm centres; but as respects each individual storm, the determining cause is not so much the average system of atmospheric circulation, as the general movement of the atmosphere going on at the time, and in the vicinity of that particular storm. The influence of this general movement is, moreover, materially modified by a variety of causes, among which may be enumerated the rainfall, and the position of the region over which it falls with respect to the centre of the storm; the size and position of neighbouring areas of high and low pressure, the distribution of temperature, and the physical configuration and character of the surface.

In further prosecuting this important discussion, the time has perhaps now come for meteorologists to give more consideration and weight to the physical conditions of the cyclone, more particularly to the method of distribution of temperature and aqueous vapour within and in the more immediate neighbourhood of the cyclone. This point, which was so strongly dwelt on and urged by Dove, has for some time past been allowed to fall too much into the background. A cyclone is not merely a system of low pressure with winds all around blowing vorticosely inwards upon the centre; but it is further distinguished by this, that the atmosphere in front of its path is relatively warm and moist, and in the rear cold and dry. These features are seldom kept so steadily in view by meteorologists as they ought to be in the discussion of such questions as Prof. Loomis has here brought under review.

One outstanding difference of the storms of America and those of Europe is that nearly all of the American storms originate on the continent, not far from the Rocky Mountains, whereas the storms of Europe originate mostly on the ocean. It is not improbable that more than one of the important points of difference between these two classes of storms shown by Prof. Loomis have their explanation in the different conditions under which they have their origin.

## OUR BOOK SHELF

*A Treatise on the Calculus of Variations.* By L. B. Carll, A.M. (London: Macmillan, 1885.)

*A Text-Book on the Method of Least Squares.* By Mansfield Merriman. (London: Macmillan, 1885.)

BOTH these works by American mathematicians have been, we believe, printed in America, and are now introduced to the attention of English students by Messrs. Macmillan. They are first-class representatives of the good work now being done in this field: we have (NATURE, vol. xvi. p. 21, vol. xxvi. p. 59) already given account of other American mathematical publications.

Mr. Carll, on his title page, states that his treatise is "arranged with the purpose of introducing, as well as illustrating, its principles to the reader by means of problems, and designed to present in all important particulars, a complete view of the present state of the science." The subject is one which certainly has not engaged the time of our book-compilers, for which good and sufficient reasons might be assigned. In 1810, as Todhunter writes, a work was published by Woodhouse, which has obtained a high reputation for accuracy and clearness. That work was not followed by any systematic treatise in English until the year 1850, when Mr. Jellett brought out his valuable "Elementary Treatise on the Calculus of Variations," an octavo volume of 377 pages, with an introduction of 20 pages. In the later editions of Mr. Todhunter's integral calculus are given such portions of the subject as are generally read by students. The same writer's "History" and "Researches" should be in the hands of all who desire to get up this branch thoroughly. After the lapse of so long an interval as thirty-five years